USDA Network Design Process

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EXECUTIVE SUMMARY

The US Department of Agriculture (USDA), Office of Operations, Telecommunications Services Division (TSD), located at Fort Collins, Colorado, analyzes and recommends strategies for cost effective interconnection of the many offices within USDA.

TSD has identified the need for a network design process to be applied uniformly throughout USDA in the selection and procurement of telecommunications services. This process should have a sound technical foundation, should be flexible and adaptable to changing technologies and their economics, and should provide USDA with defensible designs from the technical and economic perspectives.

The process described here seeks to achieve these objectives. It is general in its outlook on network design methodologies, calls for modern automated techniques, and attempts to provide comprehensive and unequivocal procedural guidance.

Guidelines are given in the areas of new service, and in the optimization of existing service. Emphasis is placed on policy, the clear specification of objectives, and the use of technically valid procedures in the selection and comparison of alternatives. The assistance of automated network design tools is stipulated, for the exploration and costing of different scenarios, survivability assessments, and the excellent designs that result from their optimization algorithms.

Findings

USDA has taken steps that ease the network design problem, by reaching a consensus on future direction, the USDA Telecommunications Architecture, restricting the range of possibilities to be explored.

The tenets of the Telecommunications Architecture are technically and economically sound. They are forward-looking and non-controversial, with many large organizations currently adopting similar strategies: backbone architecture for traffic consolidation and economies of scale; use of IP as preferred (or only) protocol, leading to simpler transport and interfaces.

Recommendations

It is recommended that this report be considered just a beginning; and that procedures be developed for keeping it up to date. Candidate areas for special consideration are the use of automated network design tools at USDA, and the characterization of USDA traffic. Input from the target audience should be encouraged.

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1. INTRODUCTION

1.1 Background

Part of the mission of the US Department of Agriculture (USDA) is to acquire and to diffuse among the people of the United States useful information on subjects connected with agriculture, rural development, aquaculture, and human nutrition, in the most general and comprehensive sense of those terms. These activities require substantial telecommunications capabilities, including:

- Local and long-distance telephone connectivity
- Interactive access to remote computers
- Electronic mail and electronic commerce
- File transfer among remote computers
- Internet and external network access
- Teleconferencing, both audio and video

The Office of Operations, National Information Technology Center (NITC), at Fort Collins, Colorado, supports the computer and communications systems used throughout USDA, providing technical leadership and consulting services across USDA programs and administrative activities. Within the NITC, the Telecommunications Services Division (TSD) analyzes and recommends strategies for cost effective interconnection of the many offices within USDA.

TSD has identified the need for a network design process to be applied uniformly throughout USDA in the selection and procurement of telecommunications services. This process should have a sound technical foundation, should be flexible and adaptable to changing technologies and their economics, and should provide USDA with defensible designs from the technical and economic perspectives.

The process will assist in the achievement of the USDA Telecommunications Architecture, and thus the objectives of the Government Performance and Results Act of 1993 and the implementation of the Information Technology Management Reform Act of 1996. The Telecommunications Architecture is USDA's framework for managing the efficient use and continued evolution of telecommunications services and systems in performing the Department's mission. It will advance consistent design of Agency work processes and enable information exchange among the automated systems that support these processes.

1.2 Objective

The objective of the Network Design Process is a set of guidelines and procedures for the design of data networks at USDA, that will satisfy the connectivity needs of USDA systems, processes, and users, while employing the most cost effective telecommunications services.

The main emphasis of the Process is on telecommunications, and decreasing overall costs while maintaining the required service levels. Mainly the interconnection of the different local units (LANs, campus). is addressed, while assuming that the local level design is technically sound, with optimized economics.

The Process is not meant to be static and inflexible. Rather, it is expected to evolve along with the best practices as determined by USDA; regular revision is anticipated.

While voice traffic represents the major portion of the total USDA telecommunications expenses, this document addresses it only incidentally, when appropriate. This is in agreement with the USDA Telecommunications Architecture, which envisions voice services as continuing to be provided by the local exchange carriers and FTS2000 (or its successor) service providers. The Architecture recognizes that the consolidation of voice and data and their transport together may be advantageous in some instances, and will be done in those cases. Video is to be handled in a similar fashion, sharing circuits and bandwidth with data when technically feasible and cost effective.

1.3 Characteristics

The Process is a roadmap to a technically sound and economical design. Its guidelines and procedures are not new or exclusive; they have been collected in this document to aid the designers and planners in keeping the overall network in focus, rather than just the domain of their current effort.

The Process is not doctrine, and is not to be accepted blindly. Technical personnel are to exercise their best technical judgment at all times. Technology and economics change so rapidly that a healthy dose of skepticism and a willingness to question the validity of all assumptions are the best and the only defensible policies.

Neither is the Process mere formality. It should be used to guide and document development, with a critical mind to detect flaws and possible improvements.

1.4 Audience

This report assumes a basic knowledge of data and voice transmissions in networks. It is directed at the personnel involved in the day-to-day process of designing, maintaining and optimizing the USDA network.

1.5 Organization

First, an enumeration of the policies governing USDA telecommunications is presented. This is followed by the USDA Network Design Process and its details. Subsequent sections provide additional relevant information, such as guidelines for the comparison of alternatives, and the range of services provided by AT&T FTS2000.

2. POLICIES

There are four major requirements for USDA telecommunications: (1) adherence to the FTS2000 services use policies; (2) adherence to the principles of the USDA Telecommunications Architecture; (3) adherence to other Departmental regulations and directives, in particular Departmental Regulation DR 3300-1 *Telecommunications*; and (4) adherence to other Government directives.

2.1 FTS2000

FTS2000 is the basic telecommunications service for the Federal Government for the years 1988-1998. It is an integrated custom network which provides voice, data, electronic mail, and video long-distance transmission service.

2.1.1 Use Guidelines

All Executive Branch Departments except Defense are required to use FTS2000 for inter-LATA tele-communications, unless granted an explicit waiver by the General Services Administration. Each Department is assigned to one of the two FTS2000 carriers – AT&T or Sprint. USDA uses AT&T (FTS2000 Network A).

Within a local access and transport area (LATA) USDA may contract directly with a local carrier, or may have FTS2000 arrange for service. In the latter case, AT&T would have full responsibility for the service, and only an FTS2000 invoice would be issued.

2.1.2 Available Services

AT&T FTS2000 provides the following services:

- Switched Voice
- Switched Data
- Dedicated Transmission Service (Leased Lines) – 4.8 Kbps analog through T1 or T3, OC-3
- Packet Switched Data
- Frame Relay (Enhanced Packet Switched) and ATM (EPSS-II)
- Video Transmission
- Switched Digital Integrated Service – includes ISDN
- Remote Site Network Connectivity (RSNC) – VSAT terminals

These services are described further in a later section.

2.2 USDA Telecommunications Architecture

The USDA Telecommunications Architecture establishes how USDA will deliver and manage all telecommunications services to meet mission area needs; it sets the rules for all future telecommunications acquisitions and for making revisions to existing networks. It is an integral part of USDA Information System Technology Architecture (ISTA) and will be supportive of the other elements of the ISTA, the technical architecture and the business/data architecture. It is a guide for the evolution of the existing Departmental and Agency data networks into a Department-wide, integrated telecommunications utility, the Enterprise Network (EN). The USDA EN is the physical implementation of the USDA Telecommunications Architecture. To reflect the existing state of the networks at any point in the migration to the EN, an inventory of network topology is needed. The inventory includes the information of users (equipment name), devices (manufacturer model), server location (IP addresses and NPANXX), and software version.

The EN is described in detail in Mitretek Report MTR 1996-10, *USDA Telecommunications Architecture*. Only highlights follow.

2.2.1 Important Characteristics

Of fundamental importance to the design process are the following characteristics: the Telecommunications Architecture imposes design restrictions; it is not fully implemented as yet; and, it is expected to evolve.

- It imposes design restrictions

  The Telecommunications Architecture has not adopted all the technologies and capabilities currently installed at USDA. Rather, it is meant to establish a USDA telecommunications environment that is optimized for maximum benefit to the Department as a whole. As a result, the architecture imposes restrictions on the design of information systems, and the characteristics of telecommunications equipment to be employed. These restrictions may negatively impact some existing information systems and Agency networks; however, a phased multi-year approach will minimize the cost and disruption associated with bringing existing systems and networks into compliance with the architecture.

- It is not fully implemented as yet

  The USDA Telecommunications Architecture is not in place. Implementation across the USDA facilities is expected to take several years. However, the long-range view must be maintained for all design work, and situations that would make attainment of the architecture's goals more difficult or more expensive are to be avoided.

- It will evolve

  The vision of the future represented by the USDA Telecommunications Architecture is expected to evolve along with USDA experience in its implementation, and in response to changes in the telecommunications environment. Technology and the associated economics change rapidly; even the major service providers to USDA may change in the upcoming competition for the successor to the FTS2000 contracts.

2.2.2 Overview of the USDA Telecommunications Architecture

The purpose of the USDA Telecommunications Architecture is to define the standard telecommunication capabilities of the department, the interrelationships of department, and agency telecommunication resources. The Telecommunications Architecture will satisfy the connectivity needs of USDA Information Technology (IT) systems, processors, and users, while employing the most effective telecommunication services. However, It will not encompass the technologies and capabilities of all existing USDA telecommunications networks.

- Traffic consolidation, backbone network, standardization

  At the nationwide level, the USDA network is to have a backbone configuration, with nodes expected to be located along with major concentrations of USDA facilities. Consolidation of traffic in the backbone and other links, and the sharing of telecommunications resources will be made possible by standardization of network interfaces and protocols. Complexity and costs will be reduced, ensuring consistent performance and reliability.

- Mandatory use of IP in the WAN

  It is intended to establish Departmental policy requiring that IP be used for all data transmissions over the wide area network (WAN) portions of the EN. Furthermore, use of IP will be required in all USDA local area networks (LANs) by the year 2002. Although continued use of other LAN protocols will be permitted until 2002, use of IP for LANs is strongly encouraged before then. Agency acquisitions must consider this requirement for the use of open LAN standards for all future acquisitions. During the interim period (from now to 2002), the use of such techniques as protocol tunneling and encapsulation for transport of non-IP protocols (*e.g.*, IBM SNA and Novel IPX) over EN WAN components is recommended.

- EN facilities will be kept separate and secure

  Any connection between USDA entities and other Government entities must be accomplished using network facilities that are separate from the EN. Completion of a Departmental waiver process is required to support any deviation from this general policy.

  A full range of security mechanisms will be available, including packet filtering, encryption, and firewalls.

2.2.3 Interim Period

Even though the USDA Telecommunications Architecture has made some of the broad selections, until it is fully in place there will have to be a balance between the requirement to promote its implementation, and the satisfaction of the needs for telecommunications in the short-term.

It is expected that each and every service request will trigger a broadening of the project's scope to include various levels of traffic consolidation. This has been an ongoing activity of TSD, at the proof-of-concept level, which now has been fully embraced by the Telecommunications Architecture.

Designs will not be done in isolation, in response to a single narrowly-stated problem, but will rather address a collection of scenarios that should be optimized and costed. Selection of which scenarios to implement would be made by upper management.

Service requests involving a certain USDA facility will, at a minimum, trigger the evaluation of the consolidation of the traffic at the facility. Additional scenarios would involve increasingly wider scopes, with different groupings of traffic considered as candidates for aggregation and/or optimization: (1) aggregation at the facility level, within the requesting Agency; (2) aggregation at the facility level, all co-located Agencies; (3) aggregation at the LATA level, within the requesting Agency; (4) aggregation at the LATA level, all USDA traffic.

The next level of aggregation coincides with the USDA network backbone design, as envisioned in the Telecommunications Architecture.

2.2.4 The Case for Regional Optimization

USDA has spent considerable effort in successfully documenting the case for savings based on traffic aggregation.

The rules for FTS2000 billing are complex, involving service initiation charges, recurring charges, and usage-based charges. Aggregation can trigger discounts to the usage charges based on traffic volume, produce lower FTS2000 access charges and reduce line charges through fuller utilization of fewer links. Often, these savings more than offset the additional costs of LEC transport of traffic to an aggregation point.

On a broader scale, regional optimization leads to reevaluation of needs, the consolidation of partially used bandwidth, and the rational development of the optimum network topology. The backbone-based Telecommunications Architecture aims at the highest consolidation-derived savings.

2.3 DR 3300-1 *Telecommunications*

This Regulation establishes policies and assigns responsibilities for the management and use of all aspects of telecommunications services, equipment, and resources within USDA. The Internet of USDA must follow the guidance in DR 3300-1 Telecommunications.

2.4 Other Government Directives

A relevant directive is OMB Circular No. A-94, *Discount Rates to Be Used in Evaluating Time-Distributed Costs and Benefits*, which gives guidelines for the benefit-cost analysis of federal programs. In compliance with this circular, telecommunications alternatives for USDA will be compared based solely upon cost. Details and procedures are presented in a later section.

3. THE USDA NETWORK DESIGN PROCESS

The long term goal of the Process is the most cost-effective telecommunications network for USDA – a fully optimized network. The Process addresses the telecommunications aspects of the USDA network; the local level (LAN, campus) is assumed optimized.

USDA has a large, operational network, with a constant stream of issues of optimization, maintenance, changes, and requests for new service. This must be taken into account in the execution of the Process; the smooth working of the network is not to be compromised.

However, in the day-to-day operations of the network, choices that would make more difficult or more expensive the attainment of the long term goal are to be avoided, even if short-term advantages are evident. There will be difficult choices, and the Telecommunications Architecture recognizes that some decisions will need to be made to the detriment of a particular application or unit; the overriding concern is to be the greater good of the entire Department.

Exhibit 3-1 depicts schematically the inputs and outcome of the USDA Network Design Process.

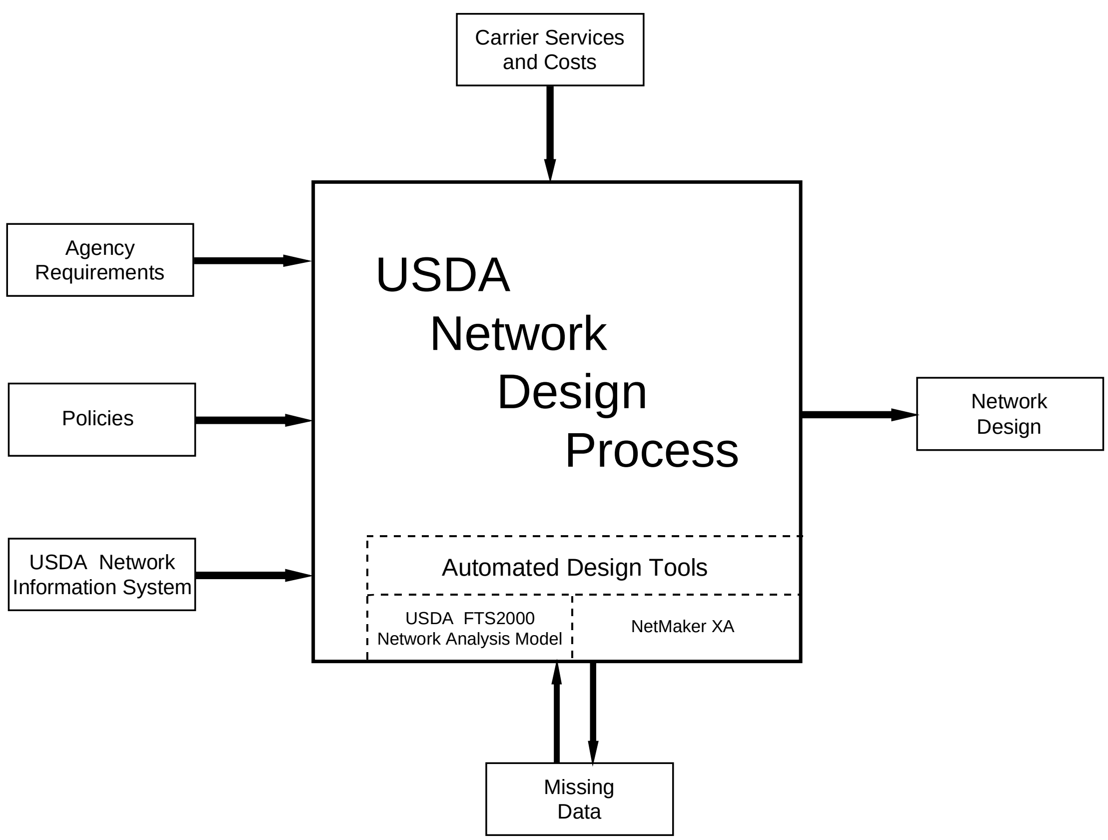

Exhibit 3-1 Inputs and Outcome of the Network Design Process

The outcome of the Process is a network design or recommendations representing the most effective ways of satisfying the connectivity requirements of the local units. As examined in Section 9, the criterion for effectiveness is cost: the mission of the Department and Agencies is to be accomplished at the lowest cost for telecommunications services.

Network design is a complex process, involving trial and error procedures and repetitive calculations with simulation demands, and the assistance of automated design tools is indicated. USDA uses the *USDA FTS2000 Network Analysis Model* software tool to analyze, optimize, and consolidate access for its networks. Also, USDA acquired a commercial network design and optimization tool, *NetMaker XA* by Make Systems Inc.; the Process assumes its use, or that of a tool with equivalent optimization capabilities.

Inputs to the process are as follows:

- Agency requirements. Typically, they would be expressed in terms of needed functionality, from which traffic and services specifications would be derived in harmony with the accomplishment of the Agency's mission and the concept of maximum benefit to the Department as a whole.
- Policies. Including directives on use of FTS2000, Departmental regulations such as DR 3300-1 *Telecommunications*, and policies such as are embodied in the USDA Telecommunications Architecture. Further details can be found in Section 2.
- USDA Network Information System. This is a collection of information on the USDA telecommunications network. An important component is a database of material associated with billing, systems administration, and equipment inventories from which useful data and insights on the USDA telecommunications traffic can be extracted. It does not provide, however, the complete description of the traffic that is required for network design.
- Carrier services and costs. These are central to network design, and are available in various forms. The automated design tools used in the Process have built-in tariffs for FTS2000 and the LECs, which provide the costs of communication links and access charges. They can be complemented by the USDA's own billing and system administration information. The carrier service and cost information allow the comparison of alternative network configurations.
- Missing data. Network design has stringent information requirements, specifically the detailed characterization of the traffic from network elements. Shortcomings or uncertainties in this characterization can only be compensated for by over-design, leading to unnecessary expense. These situations must be remedied by appropriate technical means: estimation or projection based upon experience with similar circumstances; estimation with the assistance of any available data such as billing records; direct measurement for an existing installation; finding out network elements by a discovery tool such as NetMaker XA's Discovery Agent.

3.1 Stages of the USDA Network Design Process

There are four distinct stages in the Network Design Process. The first two are of specification: of the scope of the design effort, and of the traffic requirements. The third stage is a search, for any missing information. The final stage is one of discovery, of the most effective way of satisfying the traffic requirements within the scope of the design effort.

The specification stages are accomplished through the combination of Departmental policies and the Agencies' judgment of the demands of their mission. Agencies are chartered with missions in their fields of recognized competence, and only the Agencies can determine the requirements of their mission. At USDA, telecommunications is not part of any Agency mission, but is a support function, performing the transmission of information that is required for the accomplishment of the Agencies' mandate. It is the responsibility of the Department as a whole to see that this transmission of information (the telecommunications function) is performed at the lowest possible cost.

The third and fourth stages are technical in nature, and, although elaborate and time-consuming, are straightforward. A situation that is well specified has definite data requirements, and a clearly-stated network design problem is amenable to solution by well established technical means. Automated design tools can be used in these stages.

The sections that follow address these stages in detail; subsequent sections give supporting information.

3.2 Role of the Department

The Department represents the collective responsibilities of the Agencies to external organizations. It is thus responsible for the certification that the telecommunications needs of all the USDA units are met at the lowest possible cost. For this purpose, the Department must ensure that technically appropriate design techniques are used throughout USDA.

Also, design should not be done in piecemeal fashion, or in isolation, for just the traffic of any one group. The truly lowest cost design can only be obtained by consideration of the requirements of all the units simultaneously (Department-wide optimization). This is a mathematical given. Separate optimizations, representing partial solutions under constraints that keep the traffic separate, can not be as effective as the solution to the larger problem, where all such constraints are relaxed. The Department, therefore, needs to accurately document all network elements in the USDA telecommunications network.

The Department coordinates the inter-Agency work required by the more effective optimizations.

4. STAGE I. SPECIFY THE SCOPE OF THE DESIGN EFFORT

The network design effort is directed at the optimization of a portion or all of the USDA telecommunications network. Departmental guidelines, in particular the Enterprise Network migration strategy, determine the appropriate scope of the current design effort.

Specification is needed of traffic that is to be considered for optimization, the technologies to consider, and any other institutionally-derived constraint.

This stage does not necessarily produce a single set of specifications leading to a single network design. Rather, and especially in the early stages of the implementation of the USDA Telecommunications Architecture, a range of options may be specified and explored. The Network Design Process is to be applied to each option in turn. Options may include baseline calculations, from which estimates of savings based upon before-and-after results would be derived.

4.1 Identify the Traffic Type to be Considered

Specification of the traffic to be considered for optimization may take several forms:

- Service requirements (e.g.: file transfer, remote access, video)
- Traffic characteristics such as latency, burst, and utilization must also be identified
- Prior optimization activities
- Department directives in effect:
  - by facility
  - by organization or Agency
  - by geographic location (region, LATA)
  - a combination of the above

4.2 Identify the Supporting Transport Technologies to Consider

The Enterprise Network migration strategy determines the technology or range of technologies to consider for the current design effort:

- LAN Links
- WAN Links:
  - dedicated circuits
  - Frame Relay
  - ATM

    - a combination of the above
- nodes (e.g.: routers and switches)

4.3 Identify Other Design Constraints

Any other institutionally-derived conditions to be imposed on the current design must be specified. These may include the use in the design of existing links, equipment, the location of equipment, the manufacturer of equipment, and/or software version.

The mandatory use of IP in the WAN would fall in this category once the USDA Telecommunications Architecture is fully in place.

5. STAGE II. SPECIFY THE APPLICATION REQUIREMENTS

5.1 Role of the Agencies

Agencies have exclusive expertise in their fields, and only they can establish the requirements of their mission. Information transmission requirements are to be expressed by Agencies in terms of the functionality needed in the accomplishment of their mission.

Expression of the requirements in these terms permits the selection of the manner of fulfilling the requirements so that other Government directives are satisfied. The Agencies' mission will be carried out, but at the lowest possible cost for telecommunications. This lowest-cost stipulation must be satisfied, and in a defensible manner. The USDA Network Design Process aims to represent this technically correct and defensible procedure.

5.2 Role of the Technical Personnel

In this stage, technical personnel are to translate and interpret the Agencies' requirements into a technically complete and unequivocal description suitable for design purposes. For each situation there are many possible approaches to this interpretation, depending upon the manner of specification of the requirements. It is important that a technically valid methodology be used.

In addition. technical personnel are to correct any imprecision or vagueness in the statement of requirements, and put them in quantitative terms that can be evaluated and compared impartially, and that can be presented to management and any appropriate external entity in an understandable form. A term like "acceptable performance" could be translated into "delay of less that *xx* seconds" with *xx* representing organizational guidelines for the particular application or traffic. Similarly, "reasonable reliability" might be translated into "upon failure of any single link all users will stay interconnected through bandwidth of not less than *yy* percent of normal", or "application *zz* will be backed by ISDN dial-up lines".

5.2.1 New Applications

The application designers would specify the connectivity requirements of network elements and traffic load represented by the application. Areas of uncertainty may be addressed with pilot trials of controlled scope. NetMaker XA can simulate networks with new application and determine the effects of the new service on the regional or departmental network.

5.2.2 New Facilities

Use design projections for the considered applications. Alternatively, base estimates upon the traffic load represented by the same or similar applications in existing facilities.

5.2.3 Existing Facilities

Basing the optimization of an existing network or segment upon the currently available bandwidth is not justifiable, as it may lead to gross over-design and unnecessary expense.

Existing facilities are to be optimized based upon the existing traffic. Simply put, the quality of the existing service is to be preserved in any redesign.

NetMaker XA can be used for determining current network performance, the affect of changing network components, and the impact from different traffic demands.

6. STAGE III. SEARCH FOR MISSING INFORMATION

A complete specification of the traffic is fundamental to telecommunications network design. This includes the geographical location of the sources of traffic, the traffic volume, and its characteristics or requirements. Any missing information must be secured.

In order to optimize existing facilities in the fourth stage it requires to develop a baseline of information about all networks in USDA.

6.1 Traffic Sources

Traffic demands are defined with specifying the geographic locations (i.e., NPANXXs) of the source and destination, and volume of all the traffic. This is usually done in a "network load table," which represents the required logical links between two locations.

It is helpful to visualize the problem on a map, placing the sources there along with indications of the traffic volumes. Automated design tools are capable of pictorially depicting the problem in this fashion, superimposing on a map the sources and destinations of the traffic, with links being represented by lines color coded according to the volume of traffic. NetMaker's Visualizer provides comprehensive graphical capabilities for viewing on network data.

LATA boundaries are very important because of the FTS2000 usage guidelines, and it is also helpful to differentiate the local (intra-LATA) from the long-distance (inter-LATA) traffic. However, the current version of Visualizer does not show LATA boundaries.

A possible situation is shown in Exhibit 6-1. Four LATAs are involved; LATAs A and B are adjacent to each other, C and D are remote. The links in the figure are only logical, with each link representing a network level traffic requirement.

6.1.1 Guidelines for New Facilities

For new facilities or new applications, use design projections.

6.1.2 Guidelines for the Existing Network

Existing networks are complex, often have grown in piecemeal fashion, and often there is no complete and readily available description of their characteristics. The optimization of an existing network, however, requires its description (equipment, location, link type, etc.) and that of its traffic.

The description of **all** the traffic is needed; the network redesign or optimization can only be as good as the information supplied. Misstating requirements or omission of traffic represent services that would not be provided, or missions not accomplished. Assistance in the task is provided by the USDA Network Information System, and the NetMaker XA design tool.

In order to 'discover' existing routers in networks, the SNMP function of all routers must turn on, and firewalls and other security means must allow the OCIO workstation to access routers. The discovery process defining the physical baseline definition of existing USDA data networks can be complimented by the use of available USDA FTS2000 and LEC billing records from which node locations and link types can be derived.

The comprehensive description of the USDA networks can be developed with the following sources of information:

- USDA FTS 2000 Billing Database
- USDA commercial billing data
- USDA complied network information;
    - Equipment (name, model, software with version)
    - LAN Type (Ethernet 802, Token Ring, etc.)
    - Address (IP address, physical address, NAPNXX)
    - WAN Link (type, bandwidth, Service provider)
- Simple Network Management Protocol (SNMP) discovery of:
    - Hardware Devices:
        - Routers
        - LANs
        - Frame Relay POP
        - Interface / circuit groups
        - Internet Protocol (IP) addresses
    - Transmission Connections
        - WAN links
        - LAN links
        - Frame Relay links

The WAN link type includes frame relay, both dedicated access and dial up, X.25, Switched Data Service (SDS), and Dedicated Transmission Service (DTS).

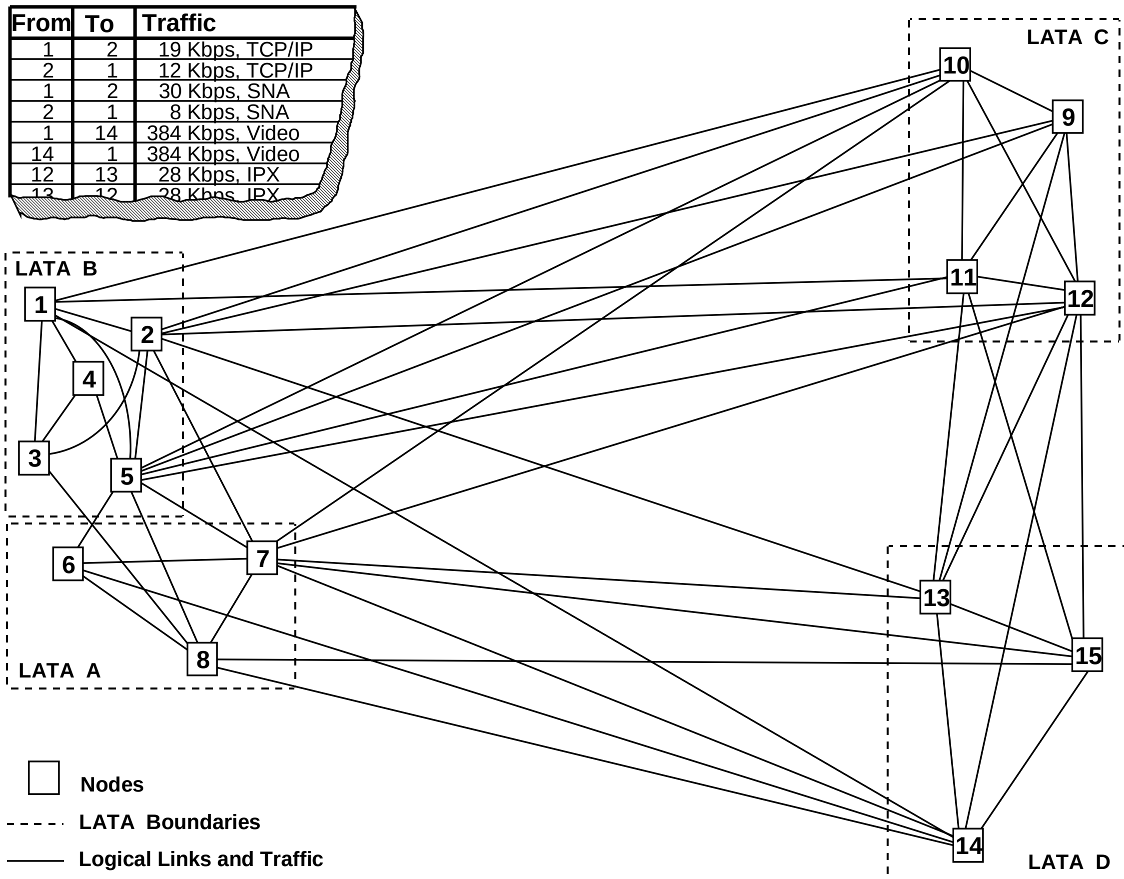

Exhibit 6-1 Logical Requirements Representation

6.1.2.1 USDA Network Information System

Although it does not contain a complete characterization of the traffic, this system should be consulted for the useful data and insights it provides on the current network. In particular, its FTS2000 and local exchange carrier records contain the location (NAPNXX) and type of service of all the traffic destined to LEC and FTS2000. The data bases are organized for easy access and use, and the generation of reports in formats suitable for other applications.

Performance-related data (peak) are available for only some traffic.

The system's billing records are very useful, in that all the traffic is represented there, and implicitly, the network topology. They offer a simple check on the completeness of the network description.

6.1.2.2 NetMaker XA

NetMaker XA consists of six tools: Visualizer; Interpreter; Planner; Analyzer; Designer; Accountant; It is a suite of design tools that helps to simplify tracking, reporting, analysis, accounting, planning, and design tasks. The applications of these tools for modeling and optimizing networks will be discussed in the Stage IV.

NetMaker XA can accept its input information through interfaces to network management systems, or in flat-file formats such as produced by the USDA Network Information System.

In addition, NetMaker XA has the important capabilities of discovery of the existing network topology, the automatic inventorying of network resources (i.e., router type, speed), and the gathering of traffic information. These features may be used to advantage in the collection and refinement of the data required for optimization purposes even though NetMaker XA cannot identify the location of network elements. The discovery feature cannot be performed when SNMP function turns off or security means like firewalls does not allow to access routers. Therefore, non-SNMP equipment need to be identified by other ways.

The NetMaker XA tool is also capable of collecting Network Level traffic (e.g.: Frame Relay) characteristics and statistics. The merging of the Network Level traffic models with the physical network configuration generates a comprehensive network model.

Application level traffic study is done by using network analyzers such as Data General's Sniffer can be used to collect data. NetMaker XA can import such data for incorporation into the network description.

The tool capabilities can also be employed to build a library of network traffic characteristics, for use with similar applications and situations. Also, the vendor can provide similarly obtained characteristics.

The tools of NetMaker XA have the following capabilities:

<u>Visualizer</u> is used for acquiring, organizing, viewing, and reporting large and complex network data. Using many subviews available by query, accurate and detailed information about the status and condition of network can be seen. Network topology can be viewed using geographical and logical layouts. It also provides management reports. It also provides ASCII import to acquire and baseline data of networks, and an Object Editor to facilitate making changes to network objects and to understand the impact of network changes.

<u>Interpreter</u> extracts and organizes information about network traffic pattern and loads this information onto the physical topology of a chosen network. Reports organize traffic by protocol type and location. Traffic profiles can be built to model effects of adding or moving users, or of merging or adding LANs. Data are then used in application planning and capacity planning to see effects of traffic pattern changes LAN/WAN utilization. Interpreter's traffic modeling capabilities are facilitated to acquire traffic data.

<u>Planner</u> provides estimates of network performance for a given routing configuration. Given the network and routing protocols on each interface, Planner attempts to reach the same routes as chosen in real network. After the route for each demand has been chosen, Planner approximately calculates utilization, delay, and throuput both for individual demands and summaries for the entire networks. Planner may help to improve utilization, reduce the time and uncertainty involved in planning and implementing changes, and identify the most optimal and cost effective deployment of network resources.

<u>Analyzer</u> helps to measure network sensitivity to changes or potential failures. Combined with Planner simulation capabilities, Analyzer's survivability and sensitivity analysis can develop recovery plans for network and natural disasters. It may provide an early warning system to avoid loss of mission-critical applications caused by transmission and equipment failures, and to identify problems that may result from changes in network loading. It also identifies the problems related to date and time of day utilization of network resources.

Designer is used for design strategies against existing networks to identify optimization in network topology or capacitation. It can automate and reduce the time required to explore alternative network topologies. It also evaluates traffic-insensitive designs or, using Planner's simulation capability, evaluates traffic-sensitive models to ensure feasibility. Therefore, it can be used for accomplishing a multitude of tasks: generate a minimum cost topology satisfying transmission requirements; generate robust networks immune to various failures; perform incremental expansion designs to accommodate additional users and /or applications; generate a design as the basis for evaluating and validating the price or performance of an existing topology; generate and compare topologies under different traffic loading conditions.

Accountant is used for determining the least-cost providers of bandwidth as well as allocate bandwidth and equipment among network users. It will set Tariff Preferences, query the tariff price established between two location points, and define/maintain user defined tariffs within the Customer Price database.

6.2 Traffic Characteristics

The most important characteristic for design purposes is the volume of traffic, in essence, the traffic between any two nodes in the network. And, typically design is based upon **peak** traffic levels; knowledge of these is imperative. NetMaker's Interpreter can be used for graphical traffic analysis in conjunction with traffic monitoring. Most telecommunications links are full-duplex, and sizing accommodates the largest peak of the two directions.

In addition, all other requirements associated with the transport must be identified. For use in the design, the required telecommunications performance must be specified in the following four ways: (1) access, (2) reliability (error), (3) throughput, and (4) response.

- Access performance is measured by blockage – the probability that a call cannot be completed. Blockage is only applicable to switched access. Access can also be measured by availability – the percentage of time the service is available. Availability is relevant for both switched and dedicated access.
- Reliability is measured by bit error rate (BER), error seconds, or degraded minutes. These quantities are primarily applicable to digital transmission. Errors in data transmission include FCS errors, retries, unsuccessful calls and rejected frames. Other quantities such as attenuation are measured in analog circuits. Reliability measures of interest for packet transmission are the number of retransmissions and the number of dropped Frame Relay frames.
- Throughput is measured by data transmitted (*e.g.,* cells, frames) per unit time. Of interest are the peak throughput, and the number of retransmissions and/or dropped packets during the peak period. Notice that throughput affects reliability when the traffic is high. Throughput is not applicable to real-time communications such as voice or video, because a channel of sufficient bandwidth is dedicated to the voice or video traffic.[1] Throughput and utilization will affect the efficiency in performance measurement.
- Response or delay is the time needed to send the data over the network. Except for satellite transmission, delay is usually not a problem in voice transmission with the normal dedicated

[1] Packetized voice/video, such as over a Frame Relay network, is another matter. Here, bandwidth is dynamically allocated, and momentary congestion can occur which can affect the transmission.

circuits. Delay can usually only be measured by test equipment attached to the customer site. In response time there are call setup, link setup and call clear time.

New applications present special problems regarding what would constitute acceptable performance. Experience, comparison with similar applications, user trials, organizational directives, provide the required guidance.

The full specification of existing service, including performance, is needed for optimization purposes, and to compare the performance of the current service with that of any alternative design. Degradation of performance should not be the outcome of any optimization or redesign effort; the performance required in the accomplishment of the Agencies' mission must be delivered. Careful specification of the requirements in clear technical terms will ensure their satisfaction.

For a more complete characterization than currently available, measurements may be undertaken on the existing traffic, for example:

For T1 transmission, test equipment equivalent to the Hewlett-Packard (HP) J2301B can measure the error seconds, the degraded minutes, and the severe error seconds. Also, network utilization over a time interval can be obtained. Its portability makes it easy to use in the field.

For fractional T1 and sub-rate transmission, test equipment equivalent to the HP 37732A can test N x 64 Kbps services, including ISDN and sub-rate services. The range of sub-rate data rates can be from 2.4 to 64 Kbps. These devices can measure errors, BER, blocking, error seconds, and delay time.

Packet switched transmission can be handled by equipment such as the HP 18300A packet network performance analyzer. These devices can measure packet throughput, frame check sequence (FCS) errors, rejected frames, unsuccessful calls, call retries, call setup time, and link setup time.

Delay measurements are best performed by a loopback test, where the circuit is routed back on itself by the remote switch. While normally used to test local loop quality, loopback tests can be run over the entire length of a circuit. All modern switches are capable of loopback test configurations. The test would consist of transmitting some test data or a signal and then waiting for it to reappear. The time measured would be the round-trip circuit delay; the one-way delay would be one-half this measurement.

Modern switching equipment such as the 5ESS, 1PSS, and DACS have built-in software-controlled performance measurement capability. Of interest to the analyst are such statistics as traffic (*e.g.,* packets, frames), blocked call attempts (for switched service), and errors (error seconds, packet rejects). These statistics are kept on a port-by-port basis, and can be collected from the maintenance port of the switch. The statistics are reported at regular time intervals, typically every 15 minutes. To obtain these statistics, the circuit must be traced to determine which switch port it occupies. The assistance of the carrier (either AT&T or the LEC) must be secured to collect the data and deliver it for analysis.

7. STAGE IV. OPTIMUM DESIGN PER SPECIFICATIONS

Upon reaching this stage, clear and complete specifications of the design parameters have been formulated:

- traffic requirements
- institutional requirements
- design constraints

This is the classic network design problem, which is amenable to solution by well-known technical means.

With the exception of trivial cases, there is no direct way of arriving at the optimum design of the network; the actual process entails trial and error and repetitive calculations. For this reason, the assistance of automated tools is indicated. NetMaker's Interpreter can measure the traffic of network models by establishing busy hour(s) and subsequent traffic utilization baseline.

To achieve network optimization, NetMaker's Planner, Analyzer, and Designer can be used for simulating network model performance, identifying potential problems, and accomplishing design goals. These tools may determine optimal backbone and access design based on accurate assessment of the current and planned network traffic and user-specified design goals.

Although the solution is quite laborious, it is relatively straightforward. Different combinations of transport services and network topologies that satisfy the design parameters are costed, and the optimum combination identified.

The requirement that FTS2000 services be used for all inter-LATA traffic simplifies matters somewhat, and the design problem reduces to the following terms: Find the most effective way to interconnect the intra-LATA traffic within each LATA involved (using LEC services, or FTS2000 services), and deliver to FTS2000 the inter-LATA traffic for transport in the most effective form and format.

Whether carried out manually, or with the assistance of automated tools, network design follows an iterative process of selecting and improving tentative topologies, until the optimum solution is found. . The optimum design needs to meet performance requirements with the least cost for the telecommunication services. The following steps can be identified:

1- Understand the application(s)' (e.g.: file transfer, video, remote access, etc.) traffic patterns, bandwidth, latency and volume requirements. This information is derived from new required applications / services such as USDA additional access to the Internet or existing services (e.g.: optimization of an existing USDA regional network).

2- Define the initial network's physical baseline satisfying the traffic requirements including: a) the selection and placement of equipment (e.g.: routers), WAN transport technology or technologies (e.g.: dedicated facility, Frame Relay, ATM), and service provider access; b) selection and placement of LAN and WAN links - for existing network baseline definition, the automated network discovery process can be used. The USDA Network Information System (see section 6.1.2.1) is used to complement the discovery process and generate the Network configuration baseline.

3- Develop the Network Level traffic baseline of the network model defined in Step 2 above. This step of the process establishes busy hours and provides expected Network links utilization applied to the physical network baseline. Network Level traffic information can be derived from SNMP discovery process and / or USDA Network Information System database(s).

4- Determine link capacity according to the traffic requirements (i.e., patterns, bandwidth usage) Determine the performance and cost of the tentative configuration. Re-size existing network links based on measured and simulated data in a design model.

5- Explore alternative topologies satisfying the performance requirements until the least-cost solution, or a range of low-cost solutions, is found.

6- Explore the survivability of the network configurations with acceptable cost parameters upon different scenarios of link failure. Modify the configurations, increasing redundancy or adjusting links to at least eliminate the possibility of major disruptions caused by the failure of any single link.

7- Present the alternatives to management.

Exhibit 7-1 presents this perspective of the network design process, emphasizing the decisions or selections to be made, and attempts to convey the repetitive or iterative nature of the procedure. The details of the process are discussed in what follows.

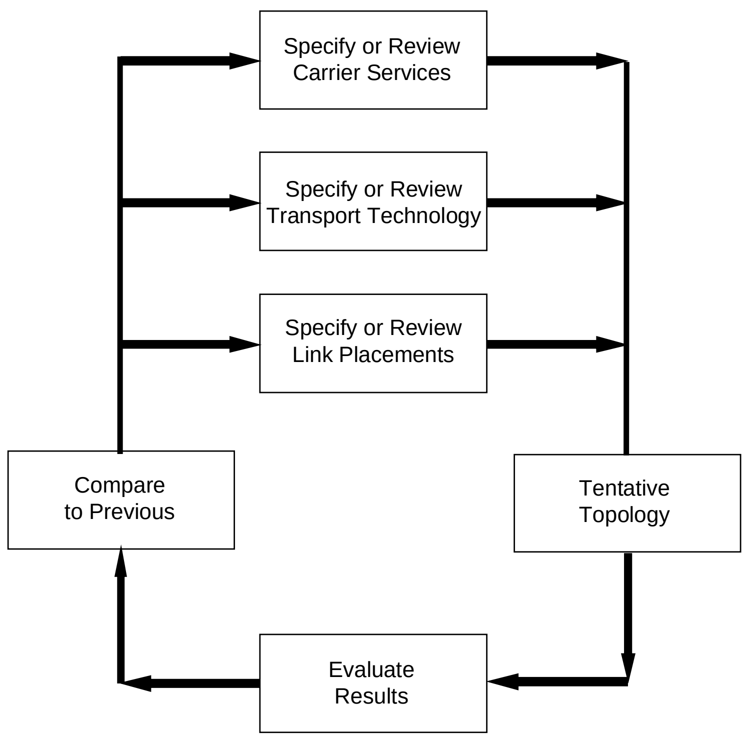

Exhibit 7-1 Decisions in Classical Network Design

7.1 Select Transport Technology, Carrier Services

Unless specified by Departmental policies, the most advantageous transport technologies and carrier services to use are unknown, to be determined by the design process. Tentative selections are made, and the best designs for each selection are compared to determine the overall optimum.

This iterative process is performed even with the automated tools. In NetMaker XA the technology specification is done manually. Eight predefined traffic demand types including a file transfer profile (FTP) and a network file server (NFS) are modeled in NetMaker XA.

7.2 Link Placements

This step seeks to determine the arrangement of physical transmission links that will carry the traffic, the network topology. Further, the topology is to be well optimized relative to cost. In a baseline analysis, the telecommunications links are known, and have known (or measurable) characteristics.

The optimization of a network with respect to performance and cost requires automation. The number of potential links that ought to be considered and evaluated fast become intractable manually, even with small numbers of locations or nodes, and modern procedures.

With N nodes, $N \times (N - 1)/2$ links will interconnect each node with every other one. There are $2^{N\times(N - 1)/2}$ ways of arranging these links, taking one, two, three, and so on, at a time, into these many possible network topologies. With 10 nodes, $10\times9/2 = 45$ links will produce a fully-meshed network (each node connected to every other one); and up to 45 of these links can be arranged into $2^{45} = 3.5\times10^{13}$ different topologies.

Modern design procedures have improved search algorithms that circumvent the consideration of all the possible permutations. Still, an overwhelming number of calculations needs to be performed.

7.2.1 The USDA FTS2000 Network Analysis Model

The *USDA FTS2000 Network Analysis Model* tool has only limited applicability to this stage of the network design. It is not intended to calculate or evaluate arbitrary network topologies; its main emphasis is on cost comparison between pure FTS2000 services, and a simple consolidation of traffic before delivery to FTS2000 by means of independently-procured LEC lines. It only considers the access to FTS2000.

Its traffic consolidation is in a radial fashion (hub-and-spoke configuration) as opposed to the generally more effective spanning tree designs. The model does consider charges appropriately, however, those of FTS2000 (access, transport) and those of the LEC plus the FTS2000 charges for the newly aggregated traffic. It can be used to provide comparison pricing for the FTS2000 portion of the network, in cases where the accuracy of the design results is in doubt.

7.2.2 New USDA Capabilities

The NetMaker XA software tool provides USDA with greatly improved design and optimization capabilities. It is capable of evaluating not only specific configurations (what-if scenarios), but also to automatically try, assess and discover more effective configurations to arrive at an optimum.

The tool offers a good degree of flexibility. It is fully integrated, and can consider both intra-LATA and the particular characteristics of FTS2000 transport and pricing. Links and traffic are assigned one or more carriers (price tables), and the tool is capable of finding automatically the optimum considering all possible arrangements of LEC and FTS2000 transport over the LATAs involved. The tool's optimizations are accurate for the carrier arrangements considered, and the nodes specified. Carrier assignments and any elements of the topology can be specified manually by the analyst in the search for the absolute optimum.

In general, the location of the traffic sources (NAPNXX) are input to the tool, along with the traffic characteristics. The physical location allows the tool to cost the LEC lines through the calculation of distances, and the identification of the service provider; the appropriate tariffs are built into the tool. In the full-optimization mode the tool will arrive by trial and error to the most cost effective topology for the situation and optimization strategy.

USDA has network information (traffic, location) in mainframe data bases derived from the billing information, part of the USDA Network Information System. From them, USDA routinely generates comma-delimited or spreadsheet-formatted information for use with the *USDA FTS2000 Network Analysis Model*. The new tool accepts similar types of input. Simple modification of the existing conversion procedures will yield data acceptable for input to the new tool. It should be repeated, however, that these data sets do not provide complete information for a network design (peak traffic levels, end-to-end traffic descriptions).

7.2.3 Link Placement Procedure

- Select the location or locations where the traffic will connect to the service provider (FTS2000, LEC). The most advantageous locations for the SDPs are not always obvious, and should be considered as additional variables in the design. NetMaker XA utilizes the concept of "candidate" nodes, which are activated only if advantageous, and can be used in the representation of the access. In this regard, the pricing details of the particular carrier services that will be used become important. Pricing for many of the FTS2000 services (voice, dedicated transmission services up to T1 speeds) does not depend upon the geographic location of the SDP within the LATA. DTS T45 (44 Mbps) is, however, priced per customer location.

  The traffic destined to another LATA may be delivered in-place to FTS2000, or may be transported, intra-LATA by the LEC, to an SDP. The intra-LATA traffic may be carried by FTS2000 (and, indirectly, by the LEC) or directly by the LEC.

- Use the new USDA automated capabilities to arrive at a trial topology for all the intra-LATA networks involved, including the traffic destined to FTS2000 facilities (with end points in different LATAs).

- Allow the tool to calculate a topology for the network, which will include each intra-LATA sub-network, and will account properly for the FTS2000 portion. This will be an optimized configuration for the assumed conditions. In a baseline calculation, or for a what-if scenario, the tool would be set to calculate without optimization.

A possible view of the optimized network is shown in Exhibit 7-2. The traffic has been aggregated for delivery to FTS2000 where appropriate, and intra-LATA traffic has been combined for effective transport. Each link in the figure may represent a variety of services (dedicated lines, fractional T1, Frame Relay), with the mix determined by Departmental policies, or the optimization process.

The figure shows a single connection point to FTS2000 at each LATA. While this may be in accord with some USDA institutional constraints, in the general case each service could very well have one or more FTS2000 SDPs distributed over the LATA.

7.3 Link Sizing, Performance, and Cost Determination

In the optimization mode, the NetMaker XA produces optimally-sized links for the assumed conditions. It help to optimize user-specified backbone costs in acceptable delays.

Similarly, performance constraints would have been considered in the calculations. The specifications are satisfied.

The tool generates costs for all the portions of the network (intra-LATA, FTS2000), including equipment expenses and line charges.

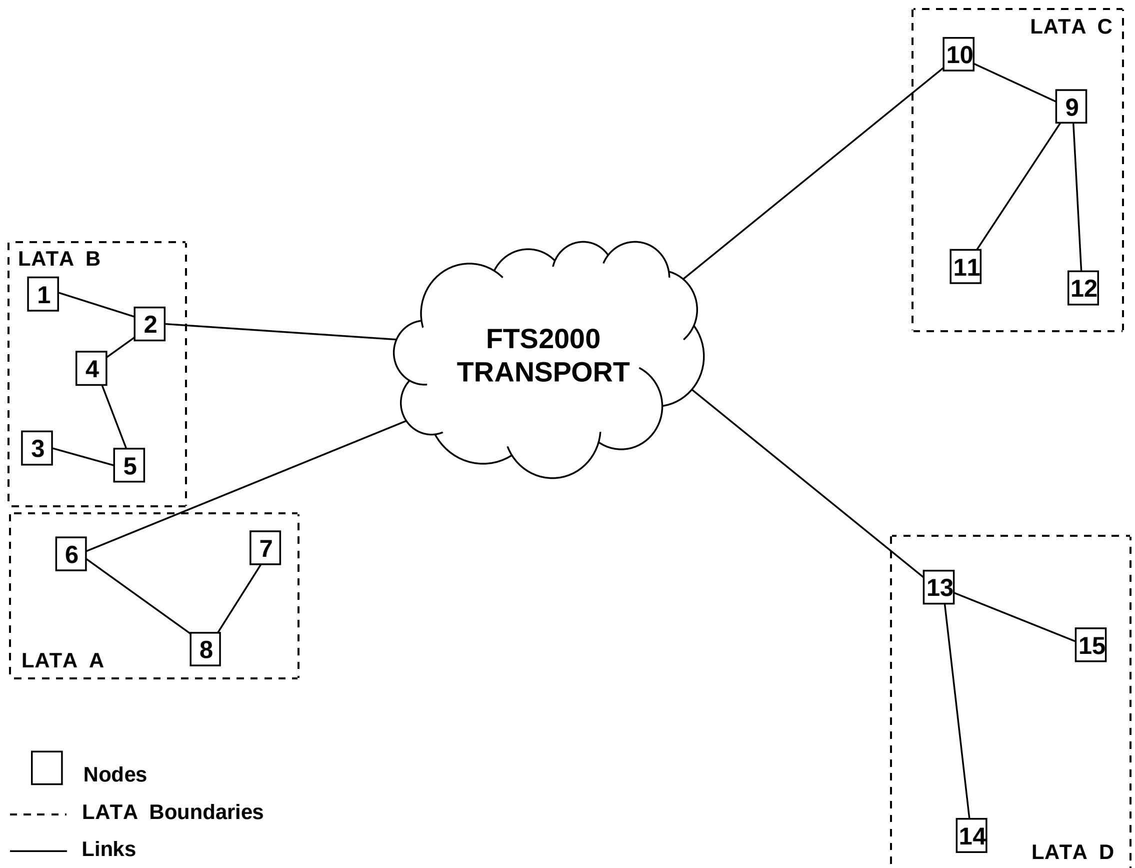

Exhibit 7-2 Possible View of the Optimized Network

7.4 Alternative Topologies

All the assumptions made must be revisited, to arrive at a truly optimized solution. In particular, the assumptions on topology involved the location of the service access, and these should be varied to determine their effects, and uncover possible improvements.

Also, if the transport technology has not been specified, other possibilities should similarly be explored (*e.g.,* dedicated circuits, Frame Relay, ATM).

7.5 Survivability

The robustness of the design has not been addressed as yet. Any raw, simply cost-optimized topology, will present many instances of links that upon failure produce isolated islands of users.

A more-fully cross-linked network is more tolerant of faults, presenting several alternative paths between nodes, that may be activated upon any link failure. The tradeoff is in added routing complexity, and the extra cost of the additional routes. The NetMaker XA software tool is capable of analyzing configurations for survivability, pinpoint potential areas of deficiency, and evaluate alternative topologies. These topologies can be run through the process, and be evaluated and optimized in turn.

Alternatively, the tool can, from the start, be constrained to base its designs on one of several pre-defined topologies with desirable survivability characteristics (cross-linking, redundancy). Results from both methods should be compared.

The carrier portion of the network has published performance specifications (e.g. FTS2000 - Section 10), and reliability is the responsibility of AT&T. Of perhaps deeper concern is the reliability of the government-owned equipment used to access the carrier network. NetMaker XA will assist in the failure analysis, and the identification of effective preventive measures.

7.6 Reporting

The outcome of the analysis is presented to management in simple to understand terms. The report should include the major assumptions, and describe the range of possibilities explored.

For each network configuration presented, the main characteristics should be described (what makes it special), along with a complete list of the main design projections (cost, performance, survivability). Tabular comparison of the alternatives is recommended.

For implementation purposes, the network designer should generate a detailed schematic of the network, including the specification of all circuits, equipment, and services. The reporting capabilities of the automated design tool can be used to advantage in these tasks.

8. FLOWCHART OF THE PROCESS

Exhibit 8-1 summarizes the USDA Network Design Process in flowchart form, highlighting the principal action and decision points. Use of the NetMaker XA design tool, or one with equivalent capabilities, is presumed.

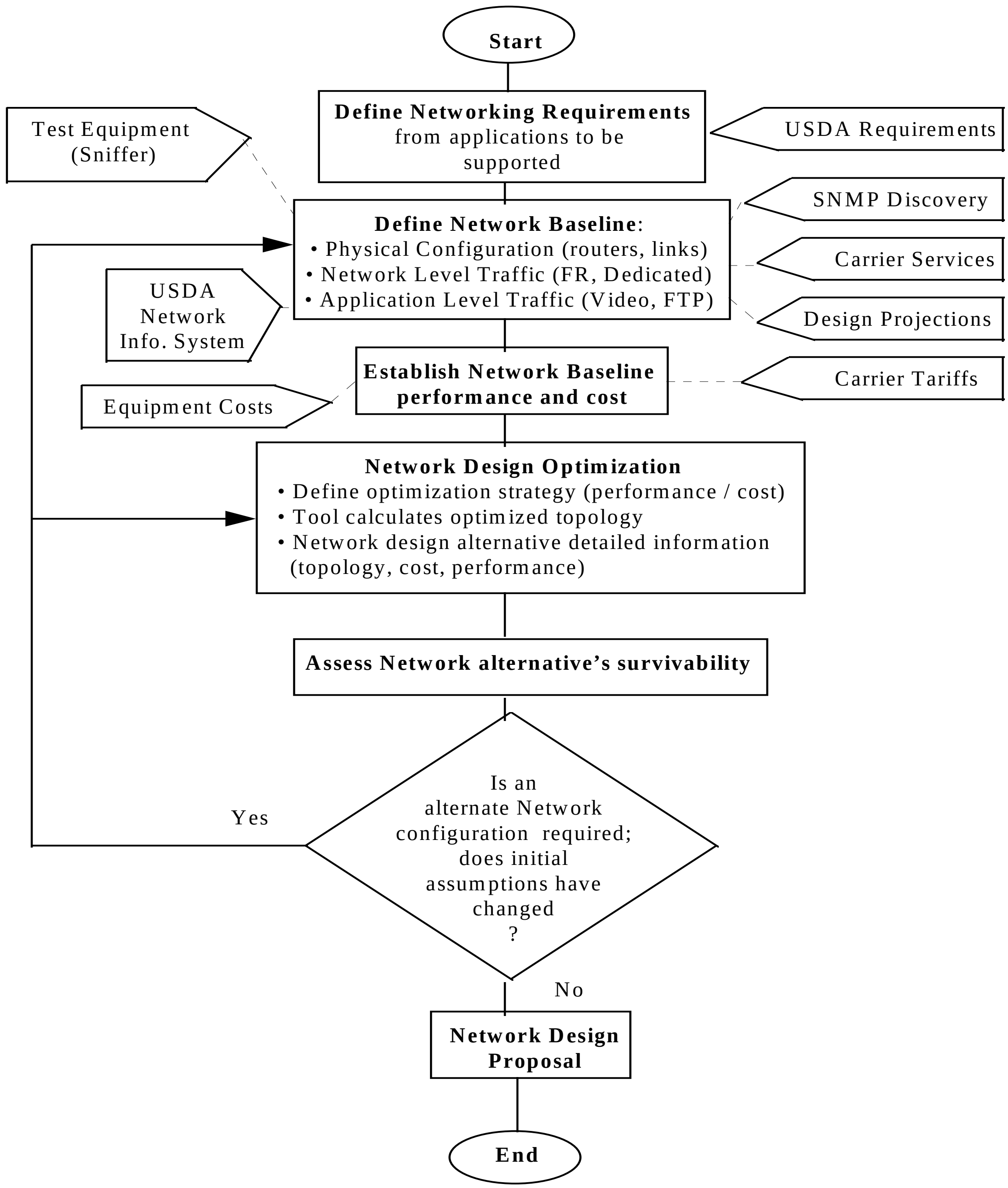

Exhibit 8-1 Flowchart of the USDA Network Design Process

9. EVALUATION AND COMPARISON OF ALTERNATIVES

The alternatives that are technically acceptable should be compared on the basis of overall cost over the period of time that the design is to be used (the life of the installation or design). This discussion will address first the acceptability of alternatives, followed by a recommended way to carry out the cost comparisons. These recommendations are consistent with OMB Circular No. A-94, which gives guidelines for benefit-cost analysis of federal programs.

9.1 Acceptable Alternatives

Acceptable alternatives for telecommunications are simply those that satisfy the minimum requirements of the task.

These minimum requirements must be determined prior to the start of the design effort, and must be agreed upon by all the parties involved (Section 5). They represent important concepts, and the validity of the entire design and selection effort hinges upon their determination and acceptance. Minimum requirements must not be changed in midstream; in case of changes the entire process should be restarted.

When evaluating alternatives, those alternatives that do not satisfy the minimum requirements **must be discarded**. It must be kept in mind that the minimum requirements represent the lowest quality of service that would allow the user, or the Agency, to perform their assigned tasks; they simply must be satisfied.

Personnel must resist the very natural tendency to slightly relax requirements so a favorite technology makes it through the process. There are, of course, circumstances that could very well warrant a reevaluation of the requirements, and it is within the scope of the duties of the technical personnel to be alert to these situations, and bring them to the attention of management. Also, it is entirely appropriate, and in fact desirable, to include these alternatives and considerations in the network design report. Typically, such an alternative would fall just short of meeting the requirements (for example, a response time 5 percent longer than specified), but would offer other clear advantages, such as greatly reduced costs. It must be emphasized, however, that any revision of the requirements can not take place without the concurrence of all the parties involved.

9.2 Comparison of Costs

The acceptable telecommunications alternatives (those that satisfy the minimum requirements) are to be compared solely on the basis of cost. This may at first appear to be a simplistic approach, but it is justified by the very nature of the telecommunications function within USDA.

Telecommunications at USDA is a support function and, however important, it is only incidental to the mission of USDA. USDA is not in the telecommunications business, but uses the technology to further its mandated goals. Federal investment in USDA telecommunications activities provides only internal benefits in the form of decreased federal costs in the accomplishment of USDA's mission. The issue is not the accomplishment of USDA's mission – this has been taken care of by the minimum requirements specification – but of doing this at the least possible cost.

9.2.1 Cost Components

Each alternative has a multitude of cost components, and a method will be described that aims at reducing these costs to a single figure, so that comparison becomes straightforward.

Each alternative has one-time costs, and costs that are distributed in time: implementation costs (equipment, installation), recurring costs (maintenance, telecommunications service charges, personnel). For a valid comparison, these costs will all be expressed in terms of a generally accepted common measure, the present value of money.

9.2.2 The Present Value

The concept is simple. The net present value cost of a certain network alternative is the amount of money one would need **today** to pay **all** the expenses over the life of the installation.

It is assumed that a portion of this money would be used immediately to pay the initial costs, with the remainder of the funds being used to pay future costs. These funds are assumed to be placed with a bank or similar investment mechanism, where they earn interest at a certain rate (the "discount rate of return") before they are spent.

The federal government evaluates economic trends and publishes figures to use for benefits-costs analysis within the federal government. The appropriate rate to use for the purposes of USDA telecommunications cost comparisons is the "nominal interest rate on Treasury notes and bonds" ("Treasury interest rate" in short) of maturity comparable to the life of the installation. These rates are issued yearly, using the Administration's economic assumptions for the budget, and are published as an update to OMB Circular No. A-94. The figures shown in Exhibit 9-1 are valid through the end of February, 1998.

Maturity	**Nominal Interest Rate (percent)**
3-Year	5.8
5-Year	5.9
7-Year	6.0
10-Year	6.1
30-Year	6.3
	These figures are valid through the end of February, 1998. Analyses of programs with terms different from those presented may use linear interpolation. For example, a four-year project can be evaluated with a rate equal to the average of the three-year and five-year rates. Programs with duration longer than 30 years may use the 30-year interest rate.

Exhibit 9-1 Nominal Interest Rates on Treasury Notes and Bonds of Specified Maturities.

These rates produce costs that include the effects of inflation. The future costs should then be expressed as actual future dollars, including the effect of inflation.

> **Note:** The government also publishes rates that have been decreased by the expected rates of inflation, for use in calculations with constant-value dollars.

9.2.3 Calculations

The discount factor is the present value of one unit of money being earned or spent a certain number of years into the future. It is calculated as

$(1 + i)^{-t}$ where i is the interest rate (expressed as fraction) and t is the number of years into the future.

Multiplying a future cost (or expense) by the appropriate discount factor yields the contribution of that particular cost (or expense) to the net present value cost of the project.

Example:

> \$100 spent 4 years from now in a project of 6-year duration contribute $100\times(1+0.0595)^{-4}$ = \$79.36 to the present value cost of the project. Note that the 6-year maturity Treasury rate of 5.95 % was obtained by interpolation in the table above.

The contributions of all significant costs must be included in the calculation of the present value cost of the project or alternative; they are simply added up. It is recommended that a clear tabulation be prepared of all the costs, time (or time schedule) at which they are incurred, the associated discount factors, and the contributions to the net present value of the total project cost.

9.2.4 Simplification

Decision among alternatives does not require a very high degree of accuracy in the cost projections. Furthermore, economic data are intrinsically uncertain, and some simplification of the cost calculations is possible, without significant loss of accuracy:

> Recurring charges that are more or less evenly distributed over one year, can be consolidated into a lump sum that is spent at the mid-point of that year.
>
> Payments for the startup expenses for the project (equipment, installation, etc.) are often distributed irregularly over a period of time, perhaps as long as one year. It would be appropriate to consider that all such expenses are paid in a lump sum 6 months into the project (year 0.5).
>
> At the end of a project, it is customary to take credit for any salvage value the facilities may have. In the rapidly changing telecommunications area, this can safely be disregarded.

In many cases also, alternatives have comparable installation costs, that are not too excessive (*e.g.*, less than the charges for one year of telecommunications services). It is appropriate then, when comparing alternatives, to simply compare the monthly recurring charges.

9.3 Sensitivity Analysis

It is often the case that a technology or a design is clearly superior; its costs are much lower than those of any alternative.

Sensitivity analysis is necessary when the outcome of the design process is not clear-cut, changing depending upon the assumptions made. The objective of sensitivity analysis is to clearly present the situation, and allow for better-informed decision making. The assumptions made in the design process are changed, and the corresponding effects upon the projected costs, or optimum network configuration are reported. The final selection among the design alternatives is deferred, since additional considerations should be weighed, usually by management.

Examples:

> Because of different capital to operating costs ratios, the optimization process results in design A when a certain inflation rate (for future costs) is assumed, and design B for another inflation rate. A and B differ by just 3 percent in the projected net present value cost (well within the margin of error of any projection in any case). Management might in this situation decide to consult an inflation expert, or simply base the decision upon other considerations (technical, social).
>
> Traffic consolidation scenarios in a certain geographical region yield two configurations with almost the same costs. Management would select one based upon its plans for the future in the area.

10. FTS2000 BASICS

The architecture of the telephone network is formed by local exchange carriers (LECs) and interexchange carriers (IECs), which interact to complete a telephone call. LEC services are provided by RBOCs and independent telephone companies, whereas IEC services are provided by long-distance companies such as AT&T, MCI, and Sprint.

Although both routing and specific architecture of the telephone network have evolved since the AT&T divestiture, the overall architecture can still be described with the basic components of a communication network. In a telephone network, each subscriber is connected via the local loop to a switching center known as an end office (EO) or central office (CO). Typically, an end office can support thousands of subscribers in a localized area. About 25,000 central offices exist in the US today. Clearly, it is impractical for each CO to be connected with a direct link. If that were the case, about 3×10^8 links are needed. Therefore, intermediate switching nodes are used. These intermediate nodes provide traffic aggregation and reduce the number of links required to connect the central offices together. The intermediate nodes are called access tandems. Each of these nodes in the network has an average of 10 to 15 central office switches connected to it. In the US, about 1,200 access tandem switches exist. Traffic routing in the LEC network is based on how the access tandems and central offices are connected.

The switching centers are connected by links called trunks. These trunks are designed to carry multiple voice frequency circuits using frequency division multiplexing (FDM) or synchronous time-division multiplexing (TDM) or wavelength division multiplexing (WDM) for fiber optics.

In a telephone network, which primarily carries voice traffic, circuit switching is the preferred switching technology. Communication via circuit switching implies a dedicated communication path between two terminals. The path is a connected segment of links between network nodes. On each physical link, a channel is dedicated to the connection. Communication via circuit switching involves the following three phases:

1. Circuit Establishment
2. Signal Transfer
3. Circuit Termination.

The circuit path is established before data transmission begins. Thus, the channel capacity must be reserved between each pair of nodes in the path, and each node must have sufficient internal switching capacity to handle the requested connection. The switches must be intelligent switches to make these allocations and route the call through the network. Some of the requirements for circuit switching are:

1. Establishing/maintaining and terminating calls on subscribers' request
2. Providing a transparent full-duplex signal
3. Providing acceptable delays for call setup (≤ 0.5 sec)
4. Providing adequate quality for the voice connection
5. Limiting blocking probability

The inter-LATA connection is shown in Exhibit 10-1.

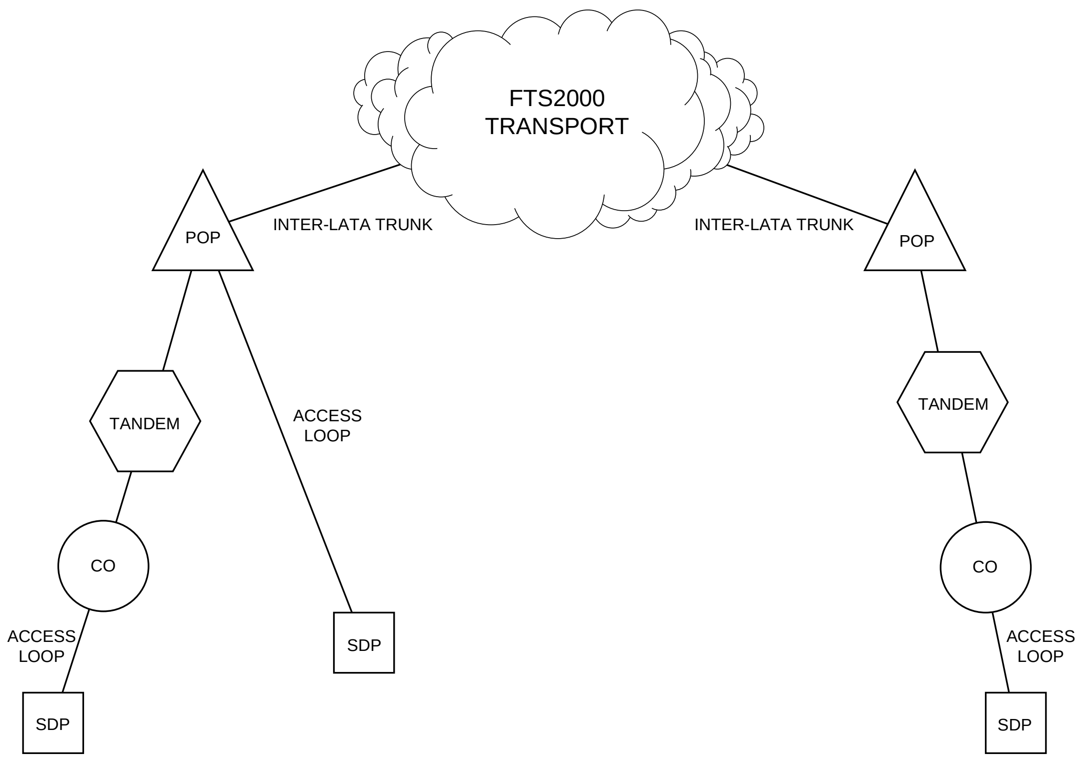

Exhibit 10-1 FTS2000 Access Configurations

10.1 FTS2000 Services

AT&T FTS2000 provides the following services:

- Switched Voice
- Switched Data
- Dedicated Transmission Service (Leased Lines) – 4.8 Kbps analog through T1 or T3, OC-3
- Packet Switched Data
- Enhanced Packet Switched Service (Frame Relay, ATM)
- Video Transmission
- Switched Digital Integrated Service (SDIS) – includes ISDN
- Remote Site Network Connectivity (RSNC) – VSAT terminals

These services and principal characteristics are briefly described below. Additional information may be found in *AT&T's FTS2000 Integrated Custom Network reference Guide.*

Switched Voice Service (SVS)

This service is the most widely used and is the most basic connection to the FTS2000 network. Without any special transmission upgrades, the SVS is normally used to provide basic voice communication.

SVS also supports connections for dial-up analog data service up to 4.8 Kbps, and will allow dial-up access to Packet Switched Service.

Switched Data Service (SDS)

SDS supports the high speed transfer of data from workstation, host computers, personal computers, terminals, facsimile, etc., from one Service Delivery Point (SDP) to another. This service is provided on a dial-up basis and is available from On-net locations to other On-net locations at 56/64 Kbps.

The High Speed Dial-Up Service provides connectivity at up to 128 Kbps to the Enhanced Packet Switched Service, and to the Internet.

ISDN-BRI like services are starting to be offered, with ISDN connectivity to other networks (LECs).

Dedicated Transmission Service (DTS)

DTS provides dedicated point-to-point and multipoint private line service for voice and data between FTS2000 SDPs. This service is provided for customers who cannot accept any contention for line access.

There are six types of DTS:

1. Dedicated Analog – provides voice and voice/data service at speeds up to and including 4.8 and 9.6 Kbps.
2. Dedicated Digital – provides synchronous full duplex with 9.6, 56, and 64 Kbps digital transmission service between FTS locations.
3. Dedicated Fractional T1 – provides 2-point connections between SDPs at 11 data rates ranging from 128 to 768 Kbps, in increments of 64 Kbps.
4. Dedicated T1 – provides point-to-point, non-channelized T1 transmission at a rate of 1.544 Mbps between FTS2000 locations.
5. Dedicated T45 – provides point-to-point, non-channelized T3 transmission at a rate of 44.736 Mbps between FTS2000 locations within the Continental US.
6. Dedicated T155 –provides point-to-point, OC-3 transmission at a rate of 155.52 Mbps between select FTS2000 locations within the Continental US. Service enhancements will provide end-to-end OC-3 capabilities and OC-3 access to asynchronous transfer mode (ATM), from customer premises to an InterSpan (AT&T's commercial ATM service) point of presence.

Packet Switched Service (PSS)

PSS is used to transmit data in packet format and provides an economical method for data communications. The user pays for the call only when packets of information are actually being transmitted. This type of transmission is especially useful for sending data when there are gaps of idle time between a terminal and computer. Telnet access to the Internet is provided for asynchronous dial up.

The FTS2000 Packet Switched Service is based on the X.25 international standard for data communications. User data is segmented into small packets that are forwarded by the network through the path of least delay to the destination. Access to PSS can be directly from the site or indirectly through a PBX. Dial-up access can be initiated on-net or off-net, but it must terminate on-net.

Enhanced Packet Switched Service (EPSS and EPSS-II)

EPSS, or Frame Relay, is designed for applications requiring bandwidths of 56 Kbps to 1.536 Mbps to accommodate sporadic periods of high volumes of data between multiple locations.

EPSS is ideal for large file transfers, image processing, and other transactions requiring larger than normal capacity. Legal or financial records, for example, can be scanned into data format for easy retrieval at whatever office needs them. Internet access is possible via PVCs at speeds up to 1.024 Mbps.

The FTS2000 Enhanced Packet Switched Service II (EPSS-II) is in the process of deployment, and uses Asynchronous Transfer Mode (ATM) technology in the multiplexing and switching of information streams between multiple locations. The FTS2000 configuration is analogous to that of the AT&T InterSpan ATM service (AT&T's commercial ATM offering). Access is through dedicated digital facilities using non channelized T3 (44.736 Mbps, with up to 35 Mbps of PVC connections) or non channelized T1 (1.544 Mbps, with up to 1.024 Mbps of PVC connections). Various service classes will be supported, along with interworking with Frame Relay.

Video Transmission Service (VTS)

Video Transmission Service provides point-to-point and multipoint video and audio transmission. There are three types of VTS available:

1. Compressed VTS (CVTS) is a digital terrestrial-based service operating at 384 Kbps. It offers color video in "near full motion." CVTS provides two-way fully interactive video and audio transmission.
2. Switched CVTS uses SDS circuits to provide compressed VTS over ISDN 56 Kbps through near-T1 channels.
3. Wide-Band VTS (WVTS) is an analog satellite-based service which provides full-color, full-motion video. It provides one-way point-to-point and multipoint video with two-way terrestrial audio return.

Switched Digital Integrated Service (SDIS)

SDIS provides FTS2000 users the capability to integrate voice, data, and video services by means of digital connections. Integrated service is available only to on-net locations. SDIS is most analogous to ISDN and establishes a way to migrate and evolve to an ISDN environment as ISDN services become available. The ISDN interface includes the Basic Rate Interface (BRI) and the Primary Rate Interface (PRI).

1. BRI is a 144 Kbps channel (two B channels of 64 Kbps and one D channel of 16 Kbps). BRI is currently not supported within SDIS (see SDS above).
2. PRI is a 1.544 Mbps trunk that can be configured as a 23B + D arrangement or 24 B channels. PRI enables voice and data transmissions within the same trunk, thus reducing the number of facilities required to provide service at a location.

Remote Site Network Connectivity (RSNC)

RSNC is used to provide FTS2000 services to remote geographic locations where there is either no LEC access or only analog access is available. This service provides a point of interface to the FTS2000 network for Switched Voice Services, Dedicated Transmission Services, and Packet Switched Services using digital access by using Very Small Aperture Terminal (VSAT) technology. This service is available at fixed sites or fly-away (portable) locations. Due to satellite coverage, this service is available in the forty-eight contiguous states only.

10.2 FTS2000 Access Types

Each of the FTS2000 services is supported by several access arrangements. The optimal access type for a given situation depends on several factors, including the local access area, traffic volume, and application. Exhibit 10-2 lists the possible access types for each service type. Originating and terminating access types are independent of each other.

10.3 Performance Standards

Published FTS2000 performance standards are as follows.

10.3.1 Error Rate

- Analog – FTS2000 Dedicated Analog Service provides voiceband data transmission at speeds up to 9.6 Kbps with a bit error rate of 10^{-5} or better.

- Digital – FTS2000 Dedicated Digital Service is designed to meet or exceed the requirement of error-free second rate of 99.84 percent. The service performance of Packet Switched Service is designed to provide a bit error rate averaged over a 5-minute period not exceeding 10^{-7}.

These error rates can be used to compare analog and digital service as follows. Packet-switched transmission involves sending packets of nominal size 128 data bytes. For a packet to be received successfully, no bit can have an error, so the analog packet error rate would be $128 \times 8 \times 10^{-5} \cong 0.01$. Thus, on an analog line, one packet in 100 would have to be retransmitted. For a digital line, the retransmission probability would be about 1 in 10,000. Whether a 1-in-100 retransmission rate would be noticeable will depend on the application which is using the data.

FTS2000 Service	Access Type
Switched Voice	On-net (analog) Off-net Virtual On-net SDIS-T1 SDIS-PRI
Switched Data	On-net (digital) SDIS-T1 SDIS-PRI
Dedicated Transmission	Dedicated analog 4.8, 9.6 Kbps Dedicated digital 9.6, 56 Kbps Dedicated unchannelized T1 (1.544 Mbps) Dedicated T45 (44 Mbps) Dedicated T155 (155.52 Mbps) SDIS-T1 SDIS-PRI Dedicated channelized T1
Packet Switched	On-net dial-up Off-net dial-up Virtual on-net 800 (basic & enhanced) Dedicated analog 2.4, 4.8, 9.6 Kbps Dedicated digital 2.4, 4.8, 9.6, 56 Kbps SDIS-T1 SDIS-PRI
Frame Relay (EPSS) ATM (EPSS-II)	Dedicated digital 56 Kbps SDIS-T1 Dedicated T1.5 (1.544 Mbps, 1.024 Mbps PVC) Dedicated T45 (44.736 Mbps, 35 Mbps PVC)
Compressed Video	Non-SDIS SDIS-T1

Exhibit 10-2 FTS2000 Access Types

10.3.2 Grade of Service

- Switched Voice Service

  The performance of AT&T FTS2000 SVS is designed to provide a 7 percent (P.07) SDP-to-SDP busy month, busy hour grade of service (GOS). This means that no more than seven out of 100 calls can be blocked during the busiest hour of the busiest month.

- Switched Data Service

  The performance of AT&T FTS2000 SDS is designed to provide a 7 percent SDP-to-SDP busy month, busy hour GOS. SDS availability is 99.8 percent on an SDP-to-SDP basis. Due in part to dynamic flexible routing (DFR), which is utilized throughout the network to optimize the use of switches and facilities, the AT&T FTS2000 Network portion is virtually non-blocking. The network is designed to respond to overload conditions in a manner that preserves network availability to as many users as possible.

- Packet Switched Service

  The service performance of PSS is designed to ensure that delay does not exceed 550 ms on average time and 900 ms for 95th percentile over 24 hours. Availability is 99.5 percent and the maximum blocking is 2 percent.

GLOSSARY

1PSS	No. 1 Packet Switching System. Bell Labs packet switch used by AT&T for FTS2000 packet switched service.
5ESS	No. 5 Electronic Switching System. Main switching system used by AT&T for FTS2000 backbone network.
ATM	Asynchronous Transfer Mode. A cell relay transmission service.
BER	Bit Error Rate
BRI	Basic Rate Interface. An ISDN offering which provides 144 Kbps aggregate transmission capacity.
CO	Central Office. Also End Office (EO). The switching center closest to the customer premises. The CO is operated by the LEC.
DACS	Digital Access and Cross-Connect System. AT&T's term for a digital cross-connect system: a computerized facility allowing DS1 lines (1.544 Mbps) to be remapped electronically at the DS0 level (64 Kbps), meaning that DS0 channels can be individually rerouted and reconfigured into different DS1 lines.
DFR	Dynamic Flexible Routing
DTS	Dedicated Transmission Service. The FTS2000 service offering non-switched (leased line) point-to-point transmission.
EN	[USDA] Enterprise Network
EPSS	Enhanced Packet Switched Service. The FTS2000 term for Frame Relay.
FCS	Frame Check Sequence. A checking code used to detect data corruption.
FDM	Frequency Division Multiplexing
GOS	Grade Of Service
IEC	Inter-Exchange Carrier. Long-distance carriers, who provide transmission services between LATAs.
Inter-LATA	1. Between local access and transport areas (LATAs). 2. associated with telecommunications that originate in one LATA and terminate in another one or that terminate outside of that LATA.
Intra-LATA	Within the boundaries of a local access and transport area (LATA).
IP	Internet Protocol. Network layer protocol in the TCP/IP stack. Documented in RFC 791.
IPX	Internetwork Packet Exchange. NetWare network layer.
ISDN	Integrated Services Digital Network. A fully digital communications facility designed to provide transparent end-to-end transmission of voice, data, video, and still images across the public switched network. Two access rates are defined: Basic Rate (144 Kbps) and Primary Rate (1.544 Mbps).
Kbps	Kilobits per second (= 1,000 bits/second)

LAN	Local Area Network
LATA	Local Access and Transport Area. The geographic area where a Local Exchange Carrier provides transport service.
LEC	Local Exchange Carrier. A carrier who provides transport service between points within a single LATA, or between an end user and an Interexchange Carrier for inter-LATA transmission.
Mbps	Megabits per second (= 1,000,000 bits/second)
NITC	[USDA] National Information Technology Center
POP	Point of Presence. The interface between an Inter-Exchange Carrier and the Local Exchange Carrier.
PRI	Primary Rate Interface. An ISDN offering which provides 1.544 Mbps aggregate transmission capacity.
PSS	Packet Switched Service. An FTS2000 service providing X.25 packet switched transmission.
RBOC	Regional Bell Operating Company. One of the seven Bell LECs created by the AT&T breakup in 1986.
RSNC	Remote Site Network Connectivity. A FTS2000 service using VSAT antennas to provide access in remote areas where Local Exchange service is not available.
SDIS	Switched Digital Integrated Service
SDP	Service Delivery Point. The point of demarcation between FTS2000 access and customer equipment.
SDS	Switched Data Service
SNA	Systems Network Architecture. Architecture from IBM.
SNMP	Simple Network Management Protocol
SVS	Switched Voice Service. The FTS2000 service providing basic voice and low-speed data communication.
TCP/IP	Transmission Control Protocol/Internet Protocol
TDM	Time Division Multiplexing
TSD	[USDA] Telecommunications Services Division
USDA	US Department of Agriculture
VSAT	Very Small Aperture Terminal. A small microwave antenna system used for satellite transmission.
VTS	Video Transmission Service
WAN	Wide Area Network
WDM	Wavelength Division Multiplexing

BIBLIOGRAPHY

AT&T, *AT&T's FTS2000 Integrated Custom Network Reference Guide*, AT&T 309-292-200 Issue 5, December 1996

Booz-Allen & Hamilton, *USDA FTS2000 Network Analysis Model Version 1.0 – Operations and Program Maintenance Manual*, March 18, 1996

Booz-Allen & Hamilton, *USDA FTS2000 Network Analysis Model Version 1.0 – User's Manual,* March 18, 1996

Hewlett-Packard, *Application Notes*

Mitretek Systems, Report MTR 1996-10, *USDA Telecommunications Architecture,* February 5, 1997

Office of Management and Budget, Circular No. A-94, *Discount Rates to Be Used in Evaluating Time-Distributed Costs and Benefits,* 1992. Appendix C on discount rates is revised yearly.

Tittel, Ed and Robbins, Margaret, *Network Design Essentials,* Academic Press, 1994

US Department of Agriculture, *Optimization and Consolidation of Telecommunications Resources*, Departmental Notice 3300-3

US Department of Agriculture, Office of Information Resources Management, *USDA Information Resources Management Strategic Plan,* January 1993

US Department of Agriculture, Office of Information Resources Management, *USDA Strategic Telecommunications Plan,* September 1993

US Department of Agriculture, *Telecommunications*, Departmental Regulation DR 3300-1, March 20, 1996. Available on-line at *http://www.net.usda.gov/internet/policy/dr3300.*

NETWORK DESIGN RESOURCES

3Com Corp., on-line information at *http://www.3com.com.* This vendor's site offers a good collection of design reports. **Note:** Mention or description of a vendor name or products does imply endorsement by the US government.

Anixter Inc., on-line information at *http://www.anixter.com.* Although directed more towards switching, this vendor's site offers good coverage of networking technology. **Note:** Mention or description here of a vendor name or products does imply endorsement by the US government.

Cisco Systems, Inc., on-line information at *http://www.cisco.com.* Although highlighting its own products, this vendor's site offers excellent coverage of routing technology. Includes white papers, case studies, and manuals for their equipment. Cisco's *Internetworking Design Guide* deserves special mention. **Note:** Mention or description here of a vendor name or products does imply endorsement by the US government.

DataPro *Data Communications Reports*, CD-ROM, various dates. This service offers up to date design guidelines and procedures. Of particular note are the reports *Frame Relay Network Design Considerations,* and *ATM Network Design and Tools.* **Note:** Mention or description here of a vendor name or products does imply endorsement by the US government.

Federal Standard 1037C, *Telecommunications: Glossary of Telecommunications Terms*, August 7, 1996, Published by General Services Administration, Information Technology Service.

Network Computing Magazine, *Interactive Network Design Manual* available on-line at *http://techweb.cmp.com.* Published by CMP Media , Inc.

US Department of Defense, *Technical Architecture Framework for Information Management (TAFIM)*, Version 3.0, 1996. The guide for architecture development mandatory for use in DOD. Provides thorough coverage of issues within the DOD environment (DISN architecture). The section on architecture concepts and design guidance provides excellent coverage of design alternatives. Available on-line at *http://www-library.itsi.disa.mil/tafim*

US Department of the Treasury, Report No. TD P 84-01, *Information System Life Cycle Manual*, Version 2.0, 1994. Excellent procedures manual for the all areas of information system development. Although not specific to telecommunications, the section on design provides thorough coverage of most issues to be encountered, documentation to be prepared, and reporting procedures. It is highly recommended.